

RESEARCH ARTICLE

The influence of haptics when assessing household products presented in different means: a comparative study in real setting, flat display, and virtual reality environments with and without passive haptics

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Abstract

This research aimed to analyse the influence of presentation means in assessing different household product characteristics and to study the influence of physical contact with the product on that assessment. To this end, the presentation of an armchair in four different means was prepared: two offering the chance to touch the product (real setting and virtual reality with passive haptics) and two not offering the physical interaction possibility (virtual reality and 3D interactive image on a screen). The product was assessed by 128 volunteers (74 men, 54 women) on a semantic scale with 12 bipolar pairs. The results revealed that the presentation means did not influence the overall product assessment, but affected the assessment of 3 of 12 features (weight, size, and aesthetics), where coming into physical contact with the product impacted the assessment of these features. Finally, similar assessments of the product were obtained in both means of visual-only presentation.

Keywords: virtual reality; passive haptics; product presentation; product evaluation; semantic differential

1. Introduction

Presentations of physical products in real settings (conventional shops, showrooms) currently co-exist with several image-based presentation telematic formats (e-commerce). In recent years, online product presentations have become more frequent owing to the ever-increasing presence of e-commerce (Jiang & Benbasat, 2007; Yoo & Kim, 2014). As new applications emerge, visual product presentation formats adapt to offer more information to potential buyers. Indeed, many shops have gone from using an online catalogue with static images to an online catalogue with interactive images, and recently to using virtual reality (VR) to show customers their products.

Several studies have concluded that different factors influence product assessments and later purchase decisions. Unal (2017) defends the importance of acquiring previous product knowledge for customers to go ahead with or go back on these decisions; Jalil, Fikry, and Zainuddin (2016) see the setting surrounding the product as a factor that can determine how it is assessed, and Chen (2018) defends product aesthetics as a conditioning factor. Other researchers (Algharabat, Alalwan, Rana, & Dwivedi, 2017; Wu et al., 2016) have verified that the quality of the images employed to present a product may make its understanding and assessment easy or difficult. Flavián, Gurrea, and Orús (2009) also add that the size of these images and movement could also be factors that contribute to purchase

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decision-making by helping consumers better understand the extent of the presented product's usability.

The increased calculation power of home computers and the prices of VR devices going down have favoured some businesses including this technology into their online catalogues. This presentation format allows coming into contact with a product more immersively and interactively than screens to experiment with the product's 3D volumetrics, which approaches real volumetrics more. This provides users with more information and improves their experience (Grewal, Noble, Roggeveen, & Nordfalt, 2020; Ozok & Komlodi, 2009; Verhagen, Vonkeman, Feldberg, & Verhagen, 2014). This can also improve consumers' product knowledge and favour their purchase intention (Jiang & Benbasat, 2004; Suh & Lee, 2005).

All this evidences the importance that image currently has on product presentation, and how it influences the way a product's characteristics and functions are perceived. In merely visual product presentation means, it is important to truthfully transmit the product's real characteristics so that consumers are suitably informed before they make a purchase decision (Saraswati, 2018).

As part of the new product design process, we see how apart from physical prototypes, virtual prototypes are also often used in their first development stages because they are cheaper and more versatile (Cecil & Kanchanapiboon, 2007). In this case, the virtual prototype must allow users to realistically experiment with the functions and characteristics that the real product will have. So essentially, this representation must be capable of transmitting reliable information. Some studies defend that VR is a suitable means in which to assess products in their different development stages (Bordegoni & Ferrise, 2013; Violante, Marcolin, Vezzetti, Nonis, & Moos, 2019; Ye, Badiyani, Raja, & Schlege, 2007). They even propose using immersive spaces to obtain a realistic context that enables the product to be assessed under conditions that come as close to the real scenario used by users/consumers as possible (Delarue & Lageat, 2019), or to analyse how the product presentation context modulates the way its features are perceived (Naderi, Naderi, & Balakrishnan, 2020). Nonetheless, different factors can affect the way that products are perceived in these settings, such as the employed technology or users feeling its presence, which can also affect how the simulated space size and distances between the various objects forming them are perceived (Ebrahimi, 2017; Ebrahimi, Babu, Pagano, & Joerg, 2016; Lok, Naik, Whitton, & Brooks, 2003; Willemsen, Gooch, Thompson, & Creem-Regehr, 2008), which may affect product assessments. Other studies also demonstrate the validity of interactive 3D images presented on screens as a resource for assessing products. Some works have explored the advantages of manipulating 3D images with mobile devices to examine the presented objects' volumetrics by several techniques (Bergé, Dubois, & Raynal, 2015), while others have used such images to assess certain affective qualities of vehicle interiors (Park, Park, Kim, Choe, & Jung, 2014) to help decision-making during the design process.

Nonetheless, completely visual presentation means do not allow products to be touched, so it is impossible to completely and reliably perceive some product characteristics, such as texture, the material's temperature to the touch, or its comfort when used or handled. Therefore, lack of tactile possibilities in visual presentation means can prevent accessing part of the product information, which could alter how some product characteristics are perceived. This could influence the product assessment during either the design process or the presentation process used to sell it (Steinmann, Kilian, & Brylla, 2014). In or-

der to avoid this, passive haptics (PH), active haptics (AH), and pseudo-haptics can be added to the VR experience.

In a VR setting, PH, defined as the use of physical elements capable of providing information to users through their shape (Lindeman, Sibert, & Hahn, 1999), can provide users with new information that supplements entirely visual information by creating a much more immersive experience. This means that a VR setting with passive haptics (VRPH), in which the position of physical objects is synchronized with virtual objects, may improve the immersion sensation in a spatial setting (Azmandian, Hancock, Benko, Ofek, & Wilson, 2016; Insko, 2001).

Moreover, AH is capable of transmitting to users the tactile sensation through a mechanical device with no physical object around. Several research works have employed wearable haptic interfaces, especially finger- and hand-related ones (Hinchet, Vechev, Shea, & Hilliges, 2018; Minamizawa, Fukamachi, Kajimoto, Kawakami, & Tachi, 2007; Minamizawa, Kamuro, Fukamachi, Kawakami, & Tachi, 2008; Pacchierotti et al., 2017), and demonstrated, on the one hand, their capacity to transmit a wide range of tactile sensations while handling virtual objects using systems that generate vibrations, pin arrays that deform skin to simulate specific shapes, and mechanisms capable of applying forces in various spatial directions (Prattichizzo, Chinello, Pacchierotti, & Malvezzi, 2013), and, on the other hand, their capacity to be simply transported to be used in different contexts.

Likewise, former studies (Biocca, Inoue, Polinsky, Lee, & Tang, 2002) and other recent ones into pseudo-haptic techniques (Collins & Kapralos, 2019; Musashi, 2019) have shown that it is possible to provide haptic information via visual and auditory information, which allows the user's experience in the virtual world to improve.

When assessing a product and determining the purchase experience, haptics and visual explorations have a notable influence (Luo, Shen, & Liu, 2019; Schifferstein & Cleiren, 2005). Visual presentations help consumers to form a view about a product, influence their purchase decision (Elder & Krishna, 2012; Krishna, 2012), and contribute to create mental simulations about their use form (Elder & Krishna, 2012; Schlosser, 2003), which favour product-related cognitive activities appearing that could impact the product assessment process (Barsalou, 2008). Likewise, the information transmitted by touch is relevant for forming opinions, helps to better perceive products' true quality (Krishna & Schwarz, 2014; Peck & Childers, 2003; Schwarz, 2012), and contributes to purchase decision-making (Keng, Liao, & Yang, 2012; Peck & Wiggins, 2006). Sometimes, certain visual characteristics (e.g. cold-warm colours) can influence how some physical characteristics (light-heavy, big-small) are perceived, which demonstrates that both are related to the mental representation of a product's features (Löffler, Arlt, Torizuka, Tscharn, & Hurtienne, 2016; Löffler, Tscharn, & Hurtienne, 2018).

Using PH in VR environments has reported many benefits in recent decades. From the very beginning, Hoffman et al. (1996), Hoffman (1998), and Insko (2001) demonstrated that employing physical objects in virtual settings allowed the simulation's level of realism to improve. This has helped advance in knowledge in different fields. For instance in the medical field, PH is a proven resource that helps to improve treatment efficacy for some phobias in VR settings (Carlin, Hoffman, & Weghorst, 1997; Tardif, Therrien, & Bouchard, 2019). In the marketing field, research has been conducted into the influence of being able to touch a product on purchase decision-making (Zenner et al., 2020). In the product design field, using PH helps to assess the usability of

products in VR settings (Falcao & Soares, 2014), improve the efficiency of certain tasks that require a physical interaction (Carvalho, Nóbrega, da Silva, & Rodrigues, 2016), and develop HMI dashboards applied in simulation booths that can reduce learning times (Joyce & Robinson, 2017; Lassagne, Kemeny, Posselt, & Merienne, 2018). Recent studies also confirm that an active haptic exploring process, in which users explore the surface of a passive object with their own hands, helps to better recognize the surface properties of these objects and is, therefore, an interesting method to assess household products in VR (Velázquez et al., 2019).

Thus, if the tactile side completes a user's opinion of a product, it is feasible to understand that presentation means can influence the way a product is understood and assessed depending on whether it allows physical contact with the product or not. Nowadays, several product presentation means exist that may interest salespersons to know how a product can be perceived in each means in order to select the means that better favours their interests. Similarly, during a product's design process, designers might be interested in selecting one presentation means or another so that users can more reliably assess certain product characteristics to help to readdress some design decisions.

Given the interest shown in consumers assessing products in e-retailing, and in users assessing a product during the design process of new products, this study intended to find out how a product's characteristics are assessed in four different means that are presently employed in conventional shops, online shops, showrooms, and product design studies: two with only a visual interaction (an interactive 3D image viewed on a screen and a simulated VR immersive setting) and two with a visual-tactile interaction (a real setting with a product or physical prototype and a VR setting that allows the product to be touched).

For this purpose, we built four different testing environments in four rooms, each one for presenting the same product in a different means. We carried out the experiment enrolling 128 volunteer participants who were divided into four subgroups, where each group had to evaluate the product presented in one means. We built a semantic differential scale with 12 bipolar pairs in order to assess different parameters of the product in a seven-interval scale. Finally, to study the results we carried out a statistical analysis and conducted Kruskal-Wallis, Shapiro-Wilk, and Dunn-Bonferroni tests.

2. Research Aim and Hypotheses

Our research aim was, on the one hand, to analyse the influence of presentation means in assessing different household product characteristics and, on the other hand, to study the influence of physical contact with the product on that assessment.

To this end, a same product was presented in four different means normally used today: two offered the chance to touch the product—real setting (R) and virtual reality with passive haptics (VRPH); two presented the product, but did not offer any physical interaction—virtual reality (VR) and 3D interactive image on a screen (S).

This study put forward three initial hypotheses:

- H1: The means employed to present a household product influences users' assessments.
- H2: The presence or absence of physical contact with a household product during its presentation influences its assessment.

H3: Similar assessments are made when a household product with no physical contact is presented, regardless of the means.

3. Materials and Methods

3.1 Case study

To test the above hypotheses, an experiment was designed in which a same product was presented in four different means. Each user had access to one of the four presentations, and interacted and studied the object according to the characteristics of the means it was presented in.

The product chosen for this study was an armchair because it is a normal piece of household furniture known by all users. In order to place the armchair in a more realistic scene, some decorative objects were added.

Having selected the product to be assessed and the four presentation means, scenes were prepared in four rooms:

- (i) Room 1: real setting (R). The real armchair was placed along with the other decorative pieces. This experiment allowed users to approach the product, touch it, and to sit on it. Nonetheless, they could not interact with any other element placed in this room apart from standing or kneeling on the rug.
- (ii) Room 2: virtual reality (VR). The armchair and the rest of the scene were represented as VR. Using a VR headset, users could walk around the scene and look at the armchair from any viewing point, move their heads, and kneel down. However, they could neither touch any other element, nor stand or kneel on the rug, because these elements were not physically found in this room.
- (iii) Room 3: virtual reality with passive haptics (VRPH). In this room, the scene was exactly the same as in Room 2, but this time two physical elements were added: the armchair and the rug, which occupied the same places in their equivalent virtual experiments. The participants could touch the armchair, sit on it, look at it from any perspective, and could kneel or stand on the rug.
- (iv) Room 4: 3D interactive image on a screen (S). The same scene was shown as an interactive 3D image on a computer screen. When users moved the mouse, they could make the camera revolve from a static point to look at the scene from any angle. By using keys W (move forward) and S (move backward), they could move around the scene and around the armchair, and move closer to examine the armchair's details.

The scenes shown in Rooms 2, 3, and 4 reproduced the same conditions of lighting, sizes, and the relative position of the elements as those that appeared in the scene in Room 1 (Fig. 2).

3.2. Semantic scale

To assess the product in different means, a semantic differential scale was prepared of several bipolar pairs that acted as product descriptors. This way to collect data about a product's different parameters is quite common and has been previously used in several research works (Hsiao, Chiu, & Chen, 2008; Mondragón, Company, & Vergara, 2005).

This study employed the semantic scale used by Felip, Galán, García-García, and Mulet (2019) because the product to be assessed in both cases was the same: an armchair. This semantic scale was built using the most normally employed adjectives to

		-3	-2	-1	0	1	2	3	
PHYSIO	Comfortable								Uncomfortable
	Heavy								Light
	Large-sized								Small-sized
PSYCHO	Simple								Complex
	Useless								Practical
	Disproportionate								Well-proportioned
SOCIO	Classic								Modern
	Ugly								Nice
	Original								Common
IDEO	Tasteful								Tasteless
	Boring								Fun
	Timeless								Temporary

Figure 1: List of the bipolar pairs used to assess the armchair on a seven-interval scale.

describe an armchair. In order to more objectively know these adjectives, three different sources were selected: 12 commercial websites offering habitat products, 70 habitual users of this product, and 10 professional designers. This was done because designers and users normally describe the product differently (Crozier, 1994), and it allowed a wide spectrum of adjectives to be obtained. The adjectives that described armchairs on websites were collected, as were the adjectives that both designers and users employ to describe the 15 different armchair typologies, which were displayed using images in which each armchair was presented on a white background. By assuming that the adjectives of the three samples were equally relevant, and bearing in mind that samples were not equal, the amount of adjectives in each sample was multiplied by a correction factor so that the three quantities of adjectives were comparable to one another. Then, we selected the most repeated adjectives in each sample, which were classified according to the four pleasure categories that products may offer, defined by Tiger (1992) as: Physio-pleasure (deriving from sensorial organs); Socio-pleasure (deriving from relationships with others); Psycho-pleasure (related to cognitive and emotional reactions); and Ideo-pleasure (related to values). We decided all this to obtain a sample of adjectives that was as representative of all four categories as possible, which has also been indicated by previous works (Achiche et al., 2014). In fields like marketing, this can be useful for studying how a means can impact the adjectives in a given category. However, in the present research work, which studies the product presentation means' influence when widely assessing a product, it would seem more appropriate to contemplate the attributes in all the categories.

Of these adjectives, only those mostly repeated in each category were selected to form bipolar pairs (12 in all, three for each pleasure category). We chose to use only 12 bipolar pairs to avoid the product assessment process becoming tedious for the participants, and also because this quantity seemed enough to obtain quite a complete product assessment. In fact, other studies have shown that a large quantity of bipolar pairs is not necessary to obtain relevant information in a product assessment (Achiche et al., 2014; Perez Mata et al., 2017).

To evaluate each bipolar pair, a seven-interval scale was used because it allowed the participants to assess the product reliably and quite easily, as former studies have demonstrated (Al-Hindawe, 1996) (Fig. 1).

3.3. Stimulus

To run the experiment, four different scenes were prepared (viewed in Rooms 1 to 4). All the scenes displayed the same prod-

uct to be assessed, which was presented with a series of neutral furnishing elements to help to contextualize the object inside its setting. The product to be assessed was the dark grey Vedbo armchair from the 2020 Ikea catalogue. The other elements were also obtained from the Ikea catalogue: a beige rug (Adum), a white side table (Lack), a white plant pot (Papaja), and two white frames from the Ribba collection. To display the scene, a room was created in neutral tones to avoid distracting the participants: medium-grey walls and floor, and a light grey ceiling. Central lighting allowed all the product's details and texture to be suitably observed so they could be assessed, and was fitted more or less centrally to the room.

The Room 1 scene was prepared by employing all the real furnishing elements. To prepare scenes in Rooms 2, 3, and 4, all the furnishing elements were modelled, as were the floor, walls, and ceiling. To ensure that the visual aspect was as similar as possible to the real setting, textures scanned from the real objects were applied. The virtual setting displayed in Rooms 2, 3, and 4 was prepared with Unity 2017.4.1. To view the scenes in Rooms 2 and 3, HTC Vive 0PJT100 headsets were employed because recent studies have demonstrated that they provide a sufficiently high degree of distance perception accuracy (Hornsey, Hibbard, & Scarfe, 2020), along with HTC Vive 2PR8100 Base Station position sensors. To view the Room 4 scene, an HP 250 G6 Notebook PC laptop was used with screen size 15.6 inches, 1920 × 1080 resolution, and a Genuine Alienware MODMUO USB mouse.

3.4 Sampling

To take part in our experiment, 128 volunteers offered, of whom 74 were men and 54 were women. Their age range went from 18 to 28 years, and their mean age was 20.25 years. All the participants were studying the Degree in Industrial Design and Product Development Engineering at the Universitat Jaume I of Castellón in Spain.

3.5 Experiment protocol

The experiment took place in the morning on two days of the same week. The sample subjects were randomly divided into four groups so that each group was formed by a similar number of subjects to view each presentation means: group 1 (32 subjects) in Room 1 (R); group 2 (31) in Room 2 (VR); group 3 (32) in Room 3 (VRPH); and group 4 (33) in Room 4 (S). Figure 2 illustrates the images inside all four rooms.

The protocol was written and it helped the researchers to follow the sequence of steps during the experiment, and to address the participants in the same way:

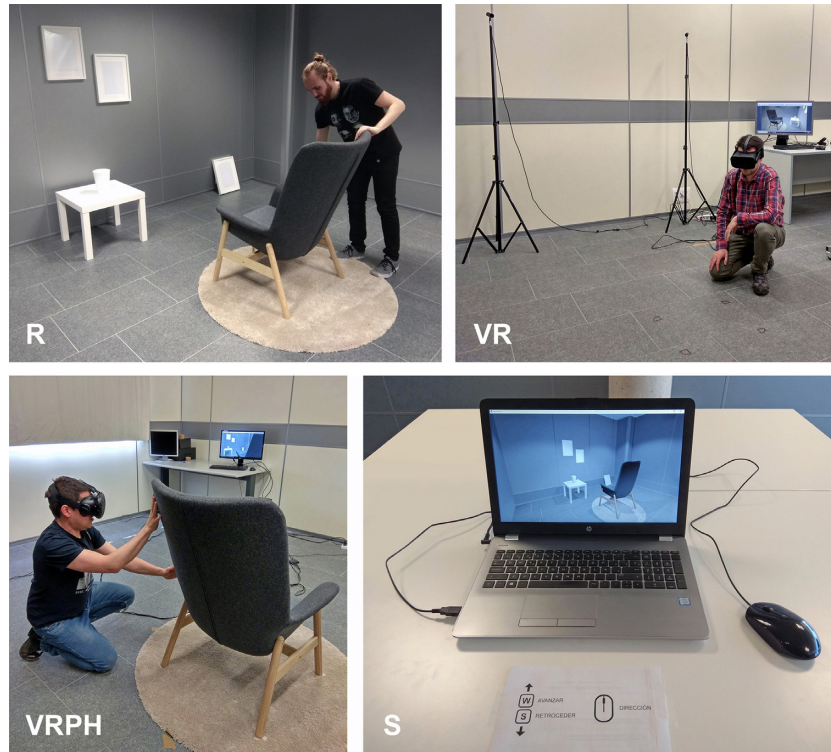


Figure 2: The participants in the different scene rooms: R (Room 1); VR (Room 2); VRPH (Room 3); S (Room 4).

STAGE 1. Welcome room (2 min).

Step 1. When the participants arrived at reception, they were registered, and asked to read and sign the consent form to perform the experiment. Then, they were accompanied to the room where the experiment would take place.

STAGE 2. Scene rooms (5 min).

Step 2. When entering Rooms 2 (VR) and 3 (VRPH), the researchers placed and fitted headsets on the participants' heads. A panel separated the small entrance area from the bigger area in which users would be presented the scene, so they could not see anything beforehand. The users directly accessed Rooms 1 (R) and 4 (S) without having to walk around a panel.

Step 3. When the participants wore headsets (Rooms 2 and 3), or had just entered (Rooms 1 and 4), a research staff member informed them that they were about to view a scene in which an armchair would be presented, which they had to later assess using a questionnaire. In each room, they were told about all the various procedures followed to view the product: in Rooms 1, 2, and 3, the participants could move around the armchair, move closer to it, move away from it, or kneel down to observe it from different viewing points. In Rooms 1 and 3, they could also touch and sit on the armchair. In Room 4, the participants were explained how they could move around the 3D setting: by moving the mouse, the users could see any part of the scene from the position they were in, and could move forward and backward using keys W and S to move the camera around the armchair, and to look closer at its details. An instruction sheet was left next to the laptop.

Step 4. For 2 min, each participant could freely view the product according to the conditions in each scene. In Rooms 2 and 3, the research staff members silently held the headset wire so that the participants would not get tangled in it.

Step 5. With the research staff members' help, the participants in Rooms 2 and 3 removed the headset behind the panel. Then, the participants in all the rooms were given a printed questionnaire and were shown where they had to go to fill it in.

STAGE 3. Survey room (5 min).

Step 6. The users filled in the questionnaire in silence. The research staff members helped the participants with any doubts they had.

The intention of the first group of questions was to collect data about the participants' age, gender, and if they had possible viewing problems that could have conditioned their visual experience using VR headsets. The purpose of the second group of questions was to know the participants' assessments of the presented product. To do so, each participant had to assess the armchair according to the 12 bipolar pairs indicated in Fig. 1. The sentence read: 'Rate the armchair you just saw according to whether you think it is closer or further away from the following adjectives (write an X in the appropriate checkbox)' for each semantic pair. The participants were asked if they had felt confident when making their assessment using one of two options: 'Yes' or 'No' ('Did you feel completely confident when you made the assessment?'). Then, they were asked to give an overall score as to how much they liked the armchair on a 5-point Likert scale, where 1 was the lowest score ('I do not like it at all') and 5 was the highest score ('I like it very much').

A blank space was left in which the participants could write any comment about the experiment that they wished to communicate to the researchers ('Would you like to add any comments about the experiment?').

Step 7. Finally, questionnaires were collected and each participant was thanked for collaborating and was accompanied to the exit.

Table 1: Descriptive statistics for the semantic scales.

Semantic scales			Conditions			
			R (N = 32)	VRPH (N = 32)	VR (N = 31)	S (N = 33)
Physio	Comfortable-Uncomfortable	Mean	−1.87	−1.75	−1.97	−1.73
		Median	−2.00	−2.00	−2.00	−2.00
		Std. Dev.	.75	1.27	.66	.72
	Heavy-Light	Mean	.56	−1.09	−.32	−.27
		Median	1.00	−1.00	−1.00	−1.00
		Std. Dev.	1.50	1.25	1.38	1.57
	Large-sized-Small-sized	Mean	−1.87	−1.47	−.77	−.67
		Median	−2.00	−2.00	−1.00	−1.00
		Std. Dev.	.94	1.05	.96	1.45
Psycho	Simple-Complex	Mean	−1.34	−.87	−1.03	−1.27
		Median	−1.50	−1.00	−1.00	−2.00
		Std. Dev.	1.04	1.04	1.43	1.44
	Useless-Practical	Mean	1.75	1.56	1.74	1.66
		Median	2.00	2.00	2.00	2.00
		Std. Dev.	.95	.87	.93	.92
	Disproportionate-Well-proportionate	Mean	.81	1.53	1.68	1.63
		Median	1.00	2.00	2.00	2.00
		Std. Dev.	1.53	1.22	1.05	1.17
Socio	Classic-Modern	Mean	.97	.87	.93	.88
		Median	1.00	1.00	1.00	1.00
		Std. Dev.	1.36	1.10	1.46	1.71
	Ugly-Nice	Mean	2.21	1.66	1.84	1.46
		Median	2.00	2.00	2.00	1.00
		Std. Dev.	.71	.90	.86	.94
	Original-Common	Mean	−.50	−.59	−.45	−.03
		Median	−1.00	−1.00	−1.00	.00
		Std. Dev.	1.32	1.32	1.41	1.66
Ideo	Tasteful-Tasteless	Mean	−1.28	−1.37	−1.29	−1.54
		Median	−2.00	−1.00	−1.00	−2.00
		Std. Dev.	1.14	.75	.78	.83
	Boring-Fun	Mean	.25	.22	.29	−1.15
		Median	.00	.00	.00	.00
		Std. Dev.	.62	.97	.94	1.09
	Timeless-Temporary	Mean	−.72	−.53	−.67	−.54
		Median	−1.00	−.50	−1.00	−1.00
		Std. Dev.	1.25	1.29	1.30	1.54

4. Results

In order to confirm or not the initial hypotheses, an inferential statistical analysis was carried out using the data obtained from the questionnaires conducted about the experiments run in the various means (R, VRPH, VR, and S). Two data types were collected: to assess the different product characteristics (using semantic pairs) and to globally assess the product (the 'I like it' question). The descriptive statistics and box plots for each semantic scale are shown in Table 1 and Fig. 3, respectively, while the overall assessment and its box plot are presented in Table 2 and Fig. 4, respectively.

Having taken the descriptive statistics from all the semantic pairs and the overall product assessment, comparing the results obtained in the different means was necessary to determine whether a statistically significant difference existed. For this purpose, a study was conducted about samples' normality and whether there were normal distributions or not, by means of the Shapiro-Wilk test, with a $\alpha = .05$.

As samples' normality was lacking, a Kruskal-Wallis test was used to establish whether there were any statistically significant differences in the semantic scale scores among the four

experimental conditions (Table 3). The null hypothesis in the Kruskal-Wallis tests determined that the mean ranges of the scores made on the semantic scales for the four experimental conditions were the same.

It was first necessary to check four assumptions:

- The dependent variable must be measured ordinally or continuously. In our case, the semantic scale scores were measured from −3 to 3.
- The independent variable must consist in two independent categorical groups or more. We had four independent groups (R, VRPH, VR, S).
- There is no relation among either the observations made in each group or the groups themselves.
- The distributions among each group must have a similar form and variability.

The Kruskal-Wallis test results are found in Table 3 and revealed that the null hypothesis was confirmed (.05 level of significance) on all the semantic scales, except for scales 'Light-Heavy', 'Large-sized-Small-sized', and 'Ugly-Nice', which are grey shaded.

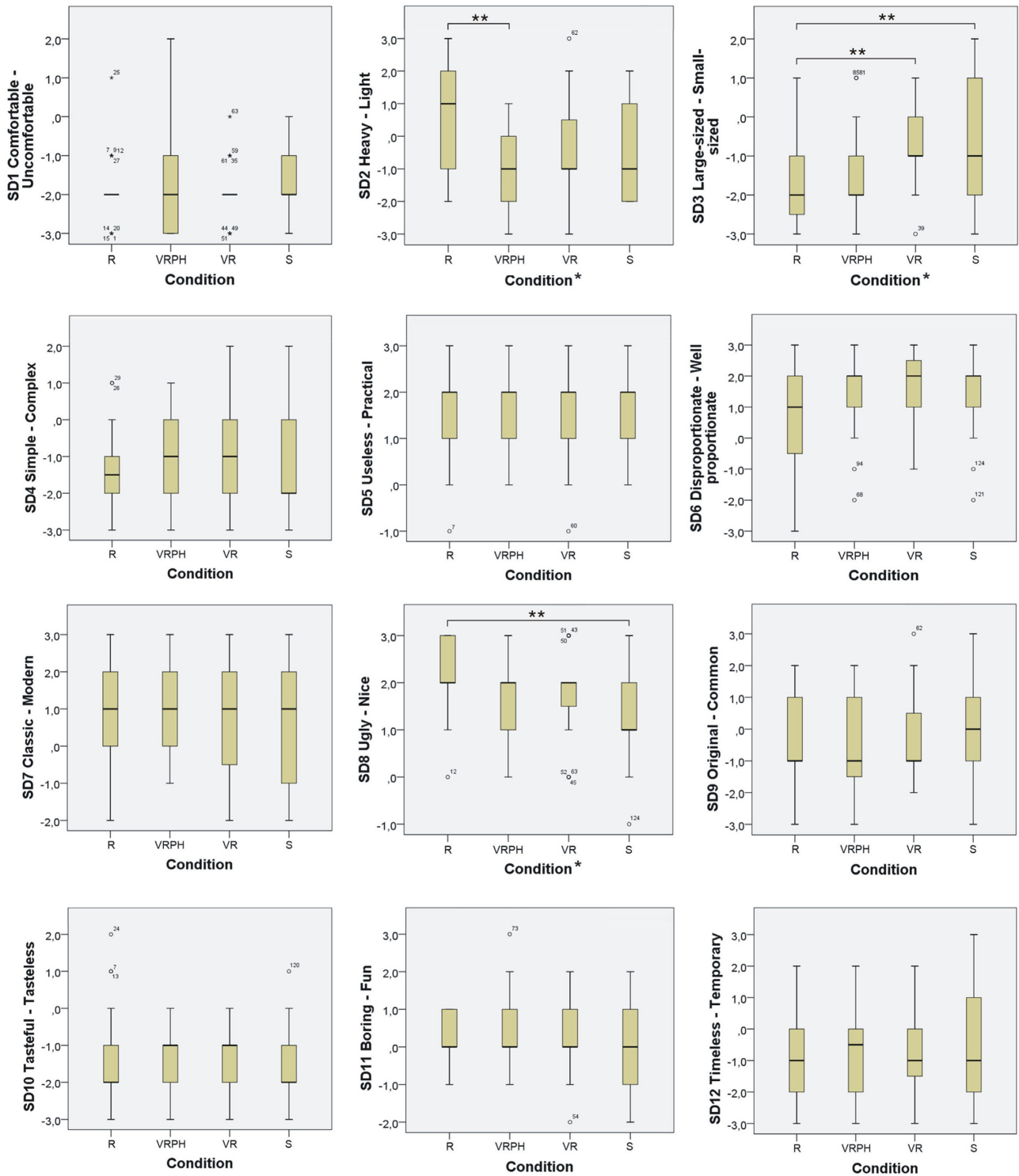


Figure 3: Box plots for the semantic scales (*indicates significant differences in the Kruskal-Wallis test; **indicates significant differences in pair-wise comparisons using the Dunn-Bonferroni test).

In order to continue the Kruskal-Wallis test, a pair-wise comparison was made in SPSS, v. 22, to determine which pairs of interaction conditions (R, VRPH, VR, S) significantly differed from one another using the Dunn-Bonferroni tests. The adjusted levels of significance are shown in Table 4, and were calculated by multiplying the unadjusted significance values by the number

of comparisons by giving a value of 1 if the product was higher than 1.

The overall assessment made by the 'I like it' question showed no statistically significant difference among conditions, and a Kruskal-Wallis test was applied ($\chi^2(3) = 2.785$, $p = .426$) because of the sample's lack of data normality.

Table 2: Descriptive statistics for the overall assessment.

Global evaluation		Conditions			
		R (N = 32)	VRPH (N = 32)	VR (N = 31)	S (N = 33)
I like it (1–5)	Mean	4.19	4.12	4.10	3.97
	Median	4.00	4.00	4.00	4.00
	Std. deviation	.53	.49	.30	.59

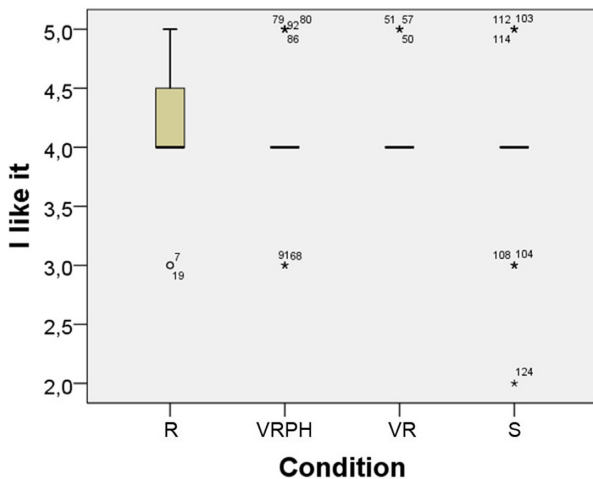


Figure 4: Box plot and histogram for the overall assessment.

5. Discussion

The Kruskal–Wallis test demonstrated that there were statistically significant differences among the assessments made for three product characteristics: differences in weight (light-heavy), size (large-sized–small-sized), and aesthetics (ugly-nice). So, we state that the means employed to present the product influenced the assessment made of it, at least for some of its characteristics. Therefore, H1 was met. This result coincides with other research works. For instance, Artacho-Ramírez, Diego-Mas, and Alcaide-Marzal (2008) compared the assessment made of a real product in four different presentation formats (photography, static infographic image, 3D navigable model, and 3D navigable stereographic model). They also concluded that the presentation means influenced the assessment made of some product characteristics.

Our study also demonstrated that significant differences appeared between some presentation means pairs: R–VRPH for heavy–light; R–S and R–VR for large-sized–small-sized; and R–S for ugly–nice. So, the results for the R–VRPH pair indicated that the product was scored more closely to the ‘Heavy’ adjective when presented in VRPH (–1.09) but, conversely, it was scored more closely to ‘Light’ when presented in R (.56). This result was unexpected because the product data collected from both means were similar (physical contact and being able to view the product on a real scale). Therefore, we would have thought that the score given to this semantic pair should have been similar. Nonetheless, other studies have warned that colours may affect how an object’s weight is perceived (Löffler et al., 2016, 2018). This might explain the results obtained in this case, although the colour used to represent the product in VRPH was similar to the real armchair’s colour. Perhaps minor tone details could have altered assessments.

Likewise with the R–S pair, the results showed that the product obtained a closer score to the ‘Large-sized’ adjective when presented in R, and was scored more closely to the ‘Small-sized’ adjective when viewed in S. This result was expected because the screen employed in S was small and, therefore, objects would have appeared smaller than they actually were, although the armchair scale compared with the other elements defining the scene was exactly the same in all the settings. A similar result was obtained for the R–VR pair because the product looked bigger in R than in VR. So, when we examined the scores given to the large-sized–small-sized semantic pair in all four means (R –1.87; VRPH –1.47; VR –.77; S –.67), we found that the least immersive the presentation setting was, the smaller this product was perceived (closer to 0 on the 7-interval scale). These results can be explained according to former studies, which defend that the immersion sensation in a means, or presence, can affect how the size of a represented space is perceived and, therefore, how objects appear in it (Heineken & Schulte, 2007).

Similarly, the results for the R–S pair indicated that the product was scored more closely to the adjective ‘Nice’ when displayed in R (2.21), but more closely to ‘Ugly’ when presented in S (1.46). Former studies have indicated that the novelty of the 3D presentation format plays a key role in forming purchase intention (Edwards & Gangadharbatla, 2001), perhaps because it is more appealing. So, although the present research did not ask the participants about their purchase intentions, we expected the product to be assessed as ‘nicer’ if presented in digital formats, which are more novel than conventional presentation formats. This result indicates that the armchair was perceived as being more appealing when presented in a real setting. Nevertheless, the second best assessment was made when the product was displayed in VR (1.84), which made us think that the novel presentation format could influence assessments after all.

The present work demonstrates that the means employed to present a household product affects users’ assessments about some of its characteristics, but the Kruskal–Wallis test indicated that the overall assessment was not affected. This means that the product does not necessarily have to be generally liked more when presented in one format or another. Although these results were not statistically significant, the assessments made by the ‘I like it’ question reveal that the more real the product presentation is, the more it is generally liked, albeit with a slight difference (R: 4.19; VRPH: 4.12; VR: 4.10; S: 3.97). These results also allowed us to see that the possibility of touching the product (in R and VRPH) could be related to it obtaining a slightly better overall assessment because some studies have shown that haptic qualities provide more product information (Krishna & Schwarz, 2014; Schwarz, 2012) and can improve its acceptance, which would favour purchase intentions (Jiang & Benbasat, 2004; Suh & Lee, 2005).

Our results also corroborate that having the chance or not to come into physical contact with a presented household product influences its assessment, and statistically significant

Table 3: Ranks and Kruskal–Wallis tests.

	Semantic scales	Condition	N	Mean rank	Kruskal–Wallis test
Physio	Uncomfortable–Comfortable	R	32	63.67	$\chi^2(3) = 2.101$ $p = .552$
		VRPH	31	60.50	
		VR	32	62.16	
		S	33	71.33	
		Total	128		
	Heavy–Light	R	32	84.03	$\chi^2(3) = 18.266$ $p < .001$
		VRPH	31	64.76	
		VR	32	45.27	
		S	33	63.97	
	Large-sized–Small-sized	Total	128		$\chi^2(3) = 22.525$ $p < .001$
		R	32	43.77	
		VRPH	31	80.50	
		VR	32	56.80	
		S	33	77.05	
Psycho	Complex–Simple	Total	128		$\chi^2(3) = 3.936$ $p = .268$
		R	32	59.03	
		VRPH	31	65.81	
		VR	32	74.34	
		S	33	59.03	
	Practical–Useless	Total	128		$\chi^2(3) = 1.248$ $p = .074$
		R	32	68.11	
		VRPH	31	67.05	
		VR	32	59.28	
	Disproportionate–Well-proportioned	S	33	63.67	$\chi^2(3) = 6.936$ $p = .074$
		Total	128		
		R	32	50.27	
		VRPH	31	69.81	
		VR	32	67.17	
Socio	Modern–Classic	S	33	70.73	$\chi^2(3) = .261$ $p = .967$
		Total	128		
		R	32	64.86	
		VRPH	31	65.81	
		VR	32	61.73	
	Ugly–Nice	S	33	65.61	$\chi^2(3) = 14.006$ $p = .003$
		Total	128		
		R	32	81.67	
		VRPH	31	66.31	
	Original–Common	VR	32	59.67	$\chi^2(3) = 2.380$ $p = .497$
		S	33	50.83	
		Total	128		
		R	32	62.84	
		VRPH	31	61.90	
Ideo	Tasteful–Tasteless	VR	32	60.22	$\chi^2(3) = 2.220$ $p < .528$
		S	33	72.70	
		Total	128		
		R	32	62.83	
		VRPH	31	69.29	
	Boring–Fun	VR	32	68.23	$\chi^2(3) = 4.023$ $p = .259$
		S	33	58.00	
		Total	128		
		R	32	69.06	
	Timeless–Temporary	VRPH	31	70.13	$\chi^2(3) = .280$ $p = .964$
		VR	32	64.72	
		S	33	54.58	
		Total	128		
		R	32	62.30	
		VRPH	31	64.03	
		VR	32	67.03	
		S	33	64.62	
		Total	128		

Note: Greyed rows identify scales where there are statistically significant differences.

Table 4: Adjusted significance levels for pair-wise comparisons by Dunn–Bonferroni tests.

Comparison	Heavy–Light	Large-sized–Small-sized	Ugly–Nice
R–VRPH	<.001	.869	.061
R–S	.155	.001	.002
R–VR	.211	<.001	.451
VRPH–S	.227	.135	1.000
VRPH–VR	.198	.051	.061
S–VR	1.000	1.000	.426

Note: Greyed columns identify comparisons of conditions where there are statistically significant differences ($p < .05$).

differences were found for the scores given for the semantic pairs large-sized–small-sized (for R–S and R–VR) and ugly–nice (for R and S). Thus, H2 was met.

Finally, H3 contemplated that similar assessments would be made of a product presented without physical contact, regardless of the means employed. As no statistically significant differences were found in the assessments made between the two means that did not allow the product to be touched (VR and S), H3 was met. Moreover, presenting a product in either VR or S did not affect the assessments made of its characteristics.

Although no statistically significant differences appeared between VR and S for the seven semantic pairs with positive and negative connotations, namely comfortable–uncomfortable, useless–practical, disproportionate–well-proportionate, ugly–nice, original–common, tasteful–tasteless, and boring–fun, we observed that more positive connotations of some of these pairs were assessed in VR, and more negative connotations were assessed in S. The armchair obtained the highest score for 'comfortable' when presented by VR, and its lowest score was when presented by S. Likewise, the product was perceived as being more practical when presented by VR, and it was nicer and more original than in S. Finally, the products' overall score was higher for 'fun' when presented in VR, and was higher for 'boring' when displayed in S.

An explanation as to why a product is assessed more positively when presented in VR than in S is beyond the present research objective, but recent studies have demonstrated that attitudes to a product can be affected by a means' level of interaction and the amount of feedback it offers. Park, Choi, Kim, and Kwon (2019) measured attitudes to a product presented in three non-tangible formats (still pictures, motion pictures, virtual graphs) and collected data using questionnaires. They concluded that an attitude to a product presented in virtual graphs (real image-based 3D contents with interactive functions) proved more positive than towards the same product displayed by the other two formats, which were less interactive. In our research, we employed different means, but the product was observed more intuitively and interactively in VR than in the less intuitive S, where it was necessary to use a mouse and keyboard to move closer and away, or to change the viewing point. This difference in the experiment's interactivity and feedback in both means could, therefore, explain the more positive attitude to the product displayed through VR.

6. Conclusions

This work studied the influence that a presentation means and coming into physical contact have when assessing 12 characteristics of a household product. This was performed by a sample of

128 people divided into four subgroups. Each subgroup assessed the same armchair presented in a different means: two means offered the possibility of touching the product (R and VRPH), while the other two presented the product with no physical interaction involved (VR and S).

This study first demonstrated that the semantic pairs selected and grouped in Tiger categories allowed us to accurately study the influence that a presentation means can have on the assessment of a presented product. So, it proved to be an efficient method to describe this influence on different characteristics.

Our results also revealed that when globally assessing a product, the presentation means had no significant influence, but was significant when assessing some product characteristics. Product characteristics (weight, size, and aesthetics) were influenced by the presentation means, and would be perceived differently depending on the means.

Our data also showed that including physical contact or not with the product while it was displayed would influence its assessment. Therefore, the means is important because it can make a product look bigger, smaller, nicer, or uglier. A product is perceived as being bigger in those means that allow physical contact with the product, and looks smaller in those means that do not; it was perceived as lighter in R, heavier by VRPH, nicer in R, and uglier by S. Conversely, presenting a product by VR or S was not significant because both these means obtained similar assessments to one another (barely statistically significant). So, they could be employed indiscriminately to either present products telematically or assess virtual prototypes.

These conclusions must be taken into account when selecting one means or another to assess different design alternatives in the project phase because the scores given to some important characteristics (physical and aesthetic) can be affected, which can impact subsequent design decisions. Likewise, presenting a product to be commercialized in one means or another can affect how some of its characteristics are assessed, which impacts purchase decisions. Perceiving distorted information about a product while it is being presented via virtual means can also affect users' purchase satisfaction when they are delivered the real product as some product features would differ from those they expected. Therefore, according to this study, if the real product was delivered, it would be perceived as being lighter and bigger than expected than if it was presented by any of the virtual means (VRPH, VR, S). Moreover, our results reveal that the product obtained the best product assessment for the adjective 'nice' when it is presented in a real setting; that is, when users see and touch the real product. So, if the product was presented via another means, user satisfaction with this aspect would be better than expected when they received the product.

The present study focused on assessing the perception of a furnishing product whose habitual use implies a marked tactile–physical interaction. This experiment obtained significant results only for the semantic pairs in the Physio and Socio categories. Nonetheless, assessing a single product (armchair) can imply a limitation for this study, so it would be desirable for future research to assess other similar products in all four means, such as chairs, chaise longue, or couches, to better confirm the results for this product family. In parallel, it would be interesting for future studies to verify what results this methodology would offer to assess other household products related more to the other Psycho or Ideo categories.

Considering the sample size limitations, this work can be considered a pilot study for following up research. So, it would

be interesting to check whether these results would be the same with an older sample for which the technology bias might be more pronounced and could have an unexpected effect on the assessments made in some means. Finally, it might be worth recruiting subjects who have no industrial design training, which was the degree that the subjects of the present work were studying.

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Conflict of Interest Statement

None declared.

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